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**Exercise Physiology: At a Crossroads**

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***Crossroads*** *is a point at which a crucial decision must be made that will have far-reaching consequences*

 -- Google

I

 am a ***professiona****l* exercise physiologist, not an exercise physiology educator. I do not have a PhD (my state has no PhD program), and I do not belong to an educational or medical institution, thus no journal will accept any of my research. Professionals in the field like me are largely ignored.

In 2004 I applied for and was granted a patent that may have been the single greatest advancement in the field of exercise physiology in my lifetime. The patent would allometrically scale body dimensions to make the evaluation and comparison of strength or aerobic capacity between individuals possible. With this technology, the standard error of estimating metabolic measurements and calculations used in exercise physiology today can be decreased by 20%.

It is a law of physics that smaller animals are more metabolically active than larger animals. Strength follows a two-thirds exponential ratio; if an individual’s twice as big, they would not lift twice as much, but two-thirds of twice as much. This is evident when plotting the relative strength (multiples of body weight) ratios of the world record holders in Olympic Weight lifting. These performances are shown next to predicted strengths based on a scaling of the athletes’ Mass 2/3 (1).

**Clean &Jerk + Snatch / Weight Ratios**

6

5

4

3

2

1

0

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | 56kg | 62kg | 69kg | 77kg | 86kg | 94kg | 105kg |
| Predicted |  5.4 | 5.22 | 5.04 | 4.86 | 4.68 | 4.54 | 4.38 |
| Actual | 5.45 | 5.24 | 5.18 | 4.9 | 4.59 | 4.44 | 4.19 |

**Figure 1. Predicted Strength to Weight Ratios (Mass to the Power of 2/3), Compared to Actual Strength to Weight Ratios for Current World Record Olympic Weightlifters by Weight Class** (International Weightlifting Federation Web Page).

Why would we, for example, continue using pushup tests to assess upper body strength? The 94 kg person in the above example would be at a 22.7% disadvantage to the 56 kg subject before the test even began. The military preaches everyone has an equal chance. How many military promotions were denied because pushups were not scaled based upon the soldiers body mass? How many firefighter and police candidates devoting years to physical and educational training have been denied a job because the human resources department did not allometrically scale the strength assessments, resulting in giving a less qualified smaller candidate the job?

# Aerobic Capacity

Inconsistencies regarding body dimension scaling are also evident in oxygen consumption and metabolic estimates. Larger animals are less metabolically active per pound when examining aerobic performances and metabolic rate. Without compensating for varying body dimensions when computing calories, oxygen consumption, or basal metabolic rate, accurate measurements of aerobic fitness and performance cannot be made.

Astrand (2) stated that “maximal oxygen uptake, expressed as mL·min-1·kg-2/3 is not related to body weight and may, therefore, be used as a meaningful fitness index instead of conventional methods of expressing maximal oxygen uptake as mL·kg-1, which penalizes heavy individuals.”

# Table 1: Effect of Allometric Scaling in the Hiring of Firefighter Candidates.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | n | Age (yr)) | Weight (kg) | Height (cm) | METs | cMETs |
| Unscaled |  |
| Candidates Passed | 1992 | 26.2 | 79.5 | 177.0 | 13.1 | 12.6 |
| Candidates Failed | 311 | 31.0 | 102.2 | 180.3 | 9.5 | 10.0 |
| Allometric Scaled |  |
| Candidates Passed | 2051 | 26.2 | 80.8 | 177.5 | 13 | 12.6 |
| *False Positives* | *34* | *32.4* | *70.0* | *168.9* | *10.9* | *10.1* |
| Candidates Failed | 252 | 31.9 | 96.3 | 178.1 | 9.5 | 9.7 |
| *False Negatives* | *93* | *28.9* | *105.7* | *182.6* | *10.1* | *10.7* |

 \*10.4 MET passing score

The data by Surina (3) presented in Table 1, show 40% (123/311) of the failed firefighter candidates were improperly classified on a pass/fail test for cardiorespiratory fitness when there was a lack of allometric scaling in the candidates scoring. Ninety-three candidates were *false negatives*, (BW = 105.7 kg), and thirty-four were *false positives* (BW = 70.0 kg). With the stringent physical standards in these highly competitive positions we will continue to rate lower evaluative scores and fail larger more qualified candidates in favor of smaller less qualified candidates. The impact of the lack of allometrically scaling these candidates can have devastating impact on the candidate, their families, the fire department and the human resources agencies that allow this to happen.

The smaller stature of females will tend to inflate their relative aerobic scores when reported as the traditional unit of mL·kg-1·min-1. A study of 5797 males and females by Surina (4) found that their estimated maximum oxygen consumption based on the heart rate/workload relationship on a bicycle ergometer were nearly identical at 44.4 and mL·kg-1·min-1,respectively. The average female (68.2 kg), and the average male (85.4 kg) were allometrically scaled to an average 75 kilo ***human***, giving corrected values for males and females of 46.0 and 42.6 mL·kg-1·min-1,respectively. This is a more in line with the differences in times noted between men and women in competitive endurance events.

Ulijaszek (5) states: "The value of removing the variance in performance due to size can be in highlighting the role of other factors and in that way further understanding of the processes involved." If a subject shows an increase in oxygen consumption, from exercise training, how much of the increase came about because they are smaller and more metabolically active, and how much came from the training? We don’t even know what exercise training does!

It would be both unprofessional and unethical to continue using linear models, (a subject twice as big does twice as much). These antiquated practices taught in academic institutions of today have stagnated the development of exercise physiology. Allometric scaling models of today are based in decades of supportive research consistently showing a range approaching a .67 exponential slope (6-9).

Traditional 1.00

Kleiber 0.75

Astrand 0.667

Hemmingsen 0.63

**Relationships of Oxygen Uptake (Y axis)**

**to Body Mass in Grams (X axis)**

11g

 .01 .1 1 10 100 1000

**Figure 2. The Effect of Mass on Variables Related to Oxygen Uptake.** (Traditional slope) = 1.0, Astrand, and Vaage & Hermansen slope for Max VO2 = .667, Kleibner slope for basal metabolic rate = .75, Hemmingsen slope for body surface area = .63

By adjusting strength and metabolic variables down from the one to one relationship of a linear model, to the allometrically scaled 2/3 exponential relationship involves a correction of -1/3. This can be done with the creation of a simple correction factor, (9).

**Ref. Population Weight ^(1/3)**

**Individuals Weight ^(1/3) = Correction Factor for Absolute**

**Individuals Weight ^(1/3) = Correction Factor for Relative**

**Ref. Population Weight ^(1/3)**

In the simplest terms, the cube root of the individual’s weight over the cube root of the reference population weight equals the correction factor for *relative* variables, the inverse of the equation for *absolute* variables. This correction factor is multiplied by the variable measured and becomes the individual’s allometrically scaled equivalent, (example: a *compensated MET value*, or ***c*MET**).

Once we start collecting meaningful objective measurements and outcomes in exercise physiology, we can begin to see actual physiological differences between males and females. We can predict solutions for rehydration, and we can see the impact of differing body compositions to work performance as well as assess physical work task efficiency and, for the first time, actually assess fitness! I have provided the tools, now it is time for the new generation of exercise physiologists to clean up the mess.

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